July 12, 1999
CCD Test Procedure Summary

Introduction

This is a brief outline of the testing of CCD detectors at the Detector Characterization Laboratory. (A detailed, 'working' Test Procedure is also available.) This procedure describes the approach for a typical set of tests: Read Noise, Dark Current, Charge Transfer Efficiency, Gain, Linearity, Full Well, Output Node Sensitivity, Quantum Efficiency, Point Spread Function, and Uniformity. Note that this document does not cover all testing activities at the DCL, other tests may be run based on results of any of the above tests or special requirements.

1. Test Setup Characterization

The Test Electronics are characterized for a given readout frequency to account for possible design deviations. For that, the test signal is injected at the CCD to electronics interface. Characterization includes measurement of gain (in uV/LSB), noise bandwidth, linearity and pulse response.

2. CCD Read Noise

CCD Read Noise is measured by shifting the CCD charge away from a given amplifier. This allows for the exclusion of other sources (e.g., dark current, charge injection, etc.) from the data. Three full frames are acquired for a given readout frequency; each frame is corrected for baseline drift. An FFT analysis is performed to look for interfering noise sources. Noise is calculated as a mean standard deviation for all three frames.

Noise is also measured in the classical way, by reading the CCD image using a short exposure time. Two frames are acquired and subtracted from each other to remove image irregularities. The difference between those two results is indicative of the noise component due to clocking, dark, cosmics and other sources.

Noise is measured within 10 kHz to 100 kHz frequency range at -80C and -90 C.

3. Dark Current

Dark Current is measured at -80C and -90C. At this temperature range dark rate may be as low as 2 electrons per hour. A very long exposure is required for an accurate measurement of dark current. Binning in the serial register is used (where possible) to reduce exposure time. At least three different exposure lengths are used for a given temperature. Three frames are taken for each exposure time. The frames are corrected for baseline drift and cosmic events. The dark current is calculated as an average of all frames.

In addition to average dark current, dark nonuniformity, histograms and a map of 'hot pixels' are computed.

4. CTE Gain and Sensitivity using an Fe55 source

An Fe55 X-ray source is used to determine the absolute Charge Transfer Efficiency (CTE) and system Gain. System Gain and electronics Gain are used to calculate CCD Output Node Sensitivity (Sv). Measurements are performed at -80C and -90C. Three frames are taken for each temperature. Each frame is baseline corrected if necessary. Standard methodology is used to extract serial and vertical CTE and Sv from each frame. An average of values from the three frames is used.

5. CTE, Gain, Sensitivity, Linearity and Full Well using flat field illumination

CTE, Gain, Linearity and Full Well are determined from series of flat field frames. The primary objective here is to characterize CTE versus signal intensity. The same data set is used to calculate linearity, full well and system gain.

Measurement are made at -80C and -90C. At a given temperature, a set of exposure times is designed to span the expected dynamic range of CCD. Data acquisition is set to overscan in both vertical and horizontal directions. For each exposure time at least two frames are acquired. Illumination is monitored, its value is averaged and recorded for each frame and used for data correction.

CTE is calculated from the amount of charge trailing the last pixel (EPER method). Gain is calculated using the Photon Transfer Curve method. Linearity is determined by fitting a straight line to the mean frame value and computing the relative deviation. Full Well is determined from the Photon Transfer Curve as a point where the shot noise curve departs from the theoretical slope. Sensitivity is determined from system Gain and electronics Gain measured at section 1.

6. Quantum Efficiency and Uniformity

Quantum Efficiency (QE) is measured by comparing the CCD readings with that of a calibrated, NIST traceable photodiode. The detector focal plane is first measured for flatness and intensity by scanning with a reference photodiode. After that, the CCD is moved into the focal plane position and three frames are taken for each temperature: -80C and -90C. Each frame is normalized to the reference diode readings. QE is calculated as an average for all three frames. Those normalized frames are used to compute the uniformity of QE.

QE measurements are performed with monochromatic illumination, with an approximate bandwidth of 10 nm. The spectral range is 200 nm to 1100 nm. The range of 200 nm to 400 nm is sampled at 25nm intervals; the range 400 nm to 1100 nm is sampled at 50 nm intervals.

7. Quantum Efficiency stability

This test verifies how much charge trapping takes place on the CCD back surface (due to backside thinning process). The CCD is maintained at dark and flushed before being exposed to series of rapid, flat field exposures; no flushing takes place between exposures. Relative responses are plotted as a function of time. The results are computed by comparing the values in the first frame with those in the plateau, which is established in the last few frames.

8. Point Spread Function

The Point Spread Function (PSF) is measured by scanning a pinhole in the object plane of the optical relay (Offner system), projecting its image in the focal plane and collecting frames for each position of the pinhole. The pinhole image is diffraction limited, and approximately 6 um in diameter.

The pinhole position is first adjusted so the image is centered on a selected pixel. Then, the pinhole is scanned in the x-y direction, +, - one step in each direction, in 5 um increments. Data is acquired for each step. PSF is calculated by fitting a Gaussian peak to the data. This test is performed with a monochromatic light (approx. 10 nm bandwidth) for UV (200 nm to 400nm), VIS and IR.

8a. Pixel Uniformity Test

This test is to show how an object image (star) will respond to 'spatial dithering', due to possible nonuniformity of response within the CCD pixel area. For this test, the optical system is modified to have an f# similar to the application optics. A pinhole image is projected on the CCD focal plane and the pinhole is scanned in 5 um (?) increments over a 50 x 50 um square (?). This test is performed for a few selected locations over the detector area using monochromatic light.